

AUTO-TECH
MASTERCLIPS

Training for Master Technicians



2017.1

**CAN Bus - Introduction
to Diagnosis**

VVT Fault Diagnosis

**Suspension, Advanced
Fault Diagnosis**

**Evaporative Emissions
Systems**

EGR Diagnosis

Advanced Safety Systems

**DIAGNOSING
CAN-VVT-EGR&MORE**



AUTO-TECH

MASTERCLASS

Training for Master Technicians

CAN BUS

Introduction to Diagnosis

VVT Fault Diagnosis

Suspension,
Advanced Fault Diagnosis

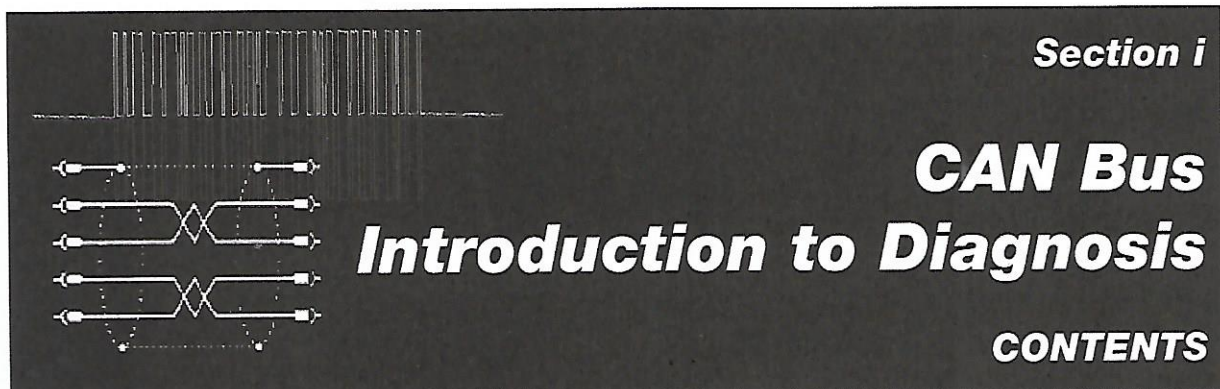
Evaporative Emission Systems

Exhaust Gas Recirculation
(EGR) Diagnosis

Advanced Safety Systems

2017.1

**DIAGNOSING
CAN, VVT, EGR & MORE**



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INTRODUCTION

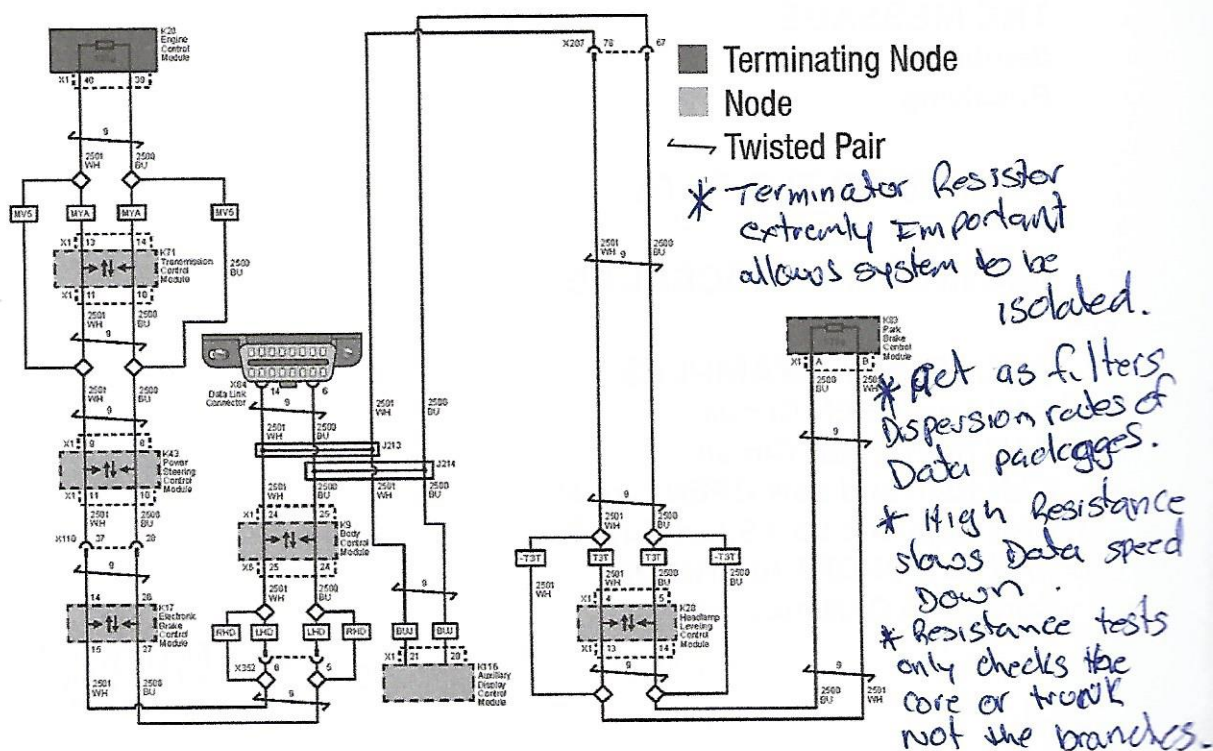
Since the full introduction of ADR79/01 (EURO III) in 2006, all vehicles in Australia and New Zealand have been required to communicate with a generic Scan Tool using a CAN Bus via the Diagnostic Connector. This therefore sets out the minimum requirement.

Quick Facts about CAN Bus:

- CAN = Controller Area Network
- Bus = is an abbreviation for Omnibus (Latin for "for all")
- Is a communication protocol
- Is used to share data between modules
- Created by Bosch in 1983
- First used by BMW in 1988
- Standard for EOBD since 2001 (Diesel 2004)
- Australian standard since ADR79/01 (EURO-III) in 2006
- Standard for OBDII from 2008

THE NETWORK

The CAN varies depending on the individual needs, this is one of the key factors of its design. It can be reduced down to the simplest system where it provides the high speed data connection between two Control Modules or expanded to provide a highly effective communication network between dozens of modules. There are limits on how many modules can use a CAN, not due to physical limitations but due to the increased traffic (signals) travelling across the network. When large numbers of modules are required to share information across a CAN, the network is broken into a collection of smaller networks with specific modules functioning on two or more networks that form gateways between the networks.

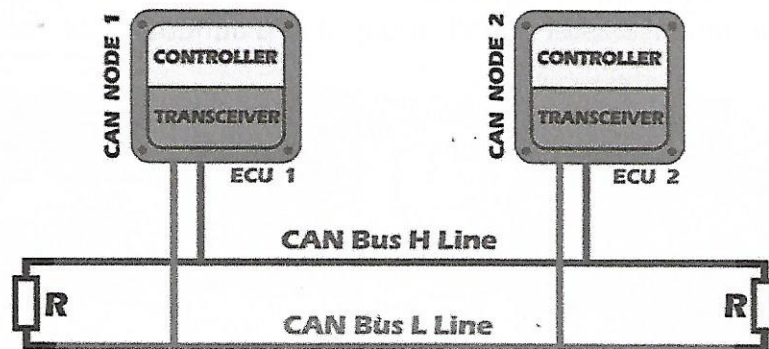


THE NETWORK continued...

A CAN consists of:

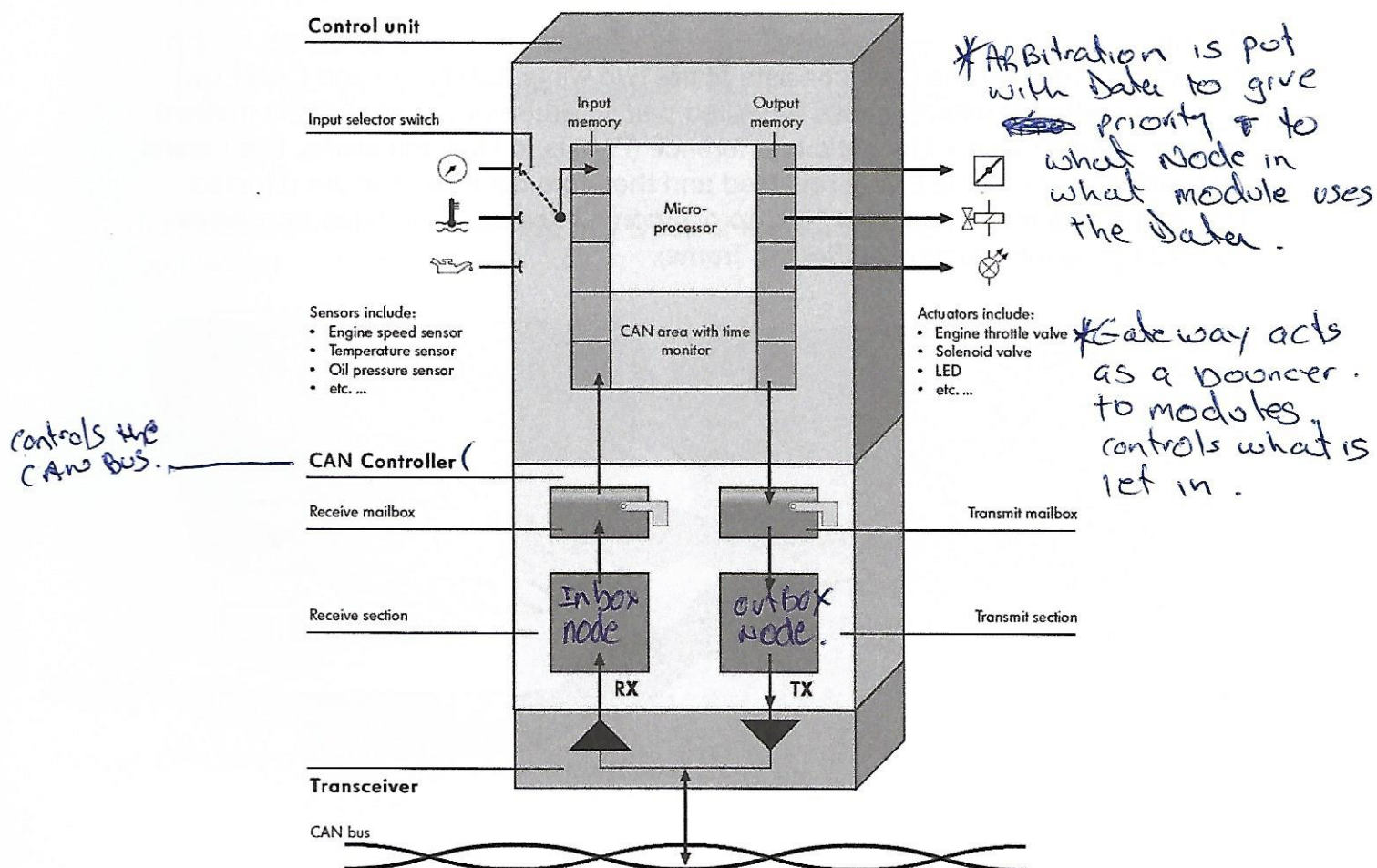
- Control Modules (referred to as Nodes on the network)
- Terminating Resistors
- Wiring
- Diagnostic Connector

*CAN High + CAN Low.
mirrors Data to Act
as Back up.



Control Modules

Any Control Module that is situated on the CAN will contain a circuit referred to as a Node. The Node includes the CAN Controller and the Transceiver, it is responsible for translating, sending and receiving messages.

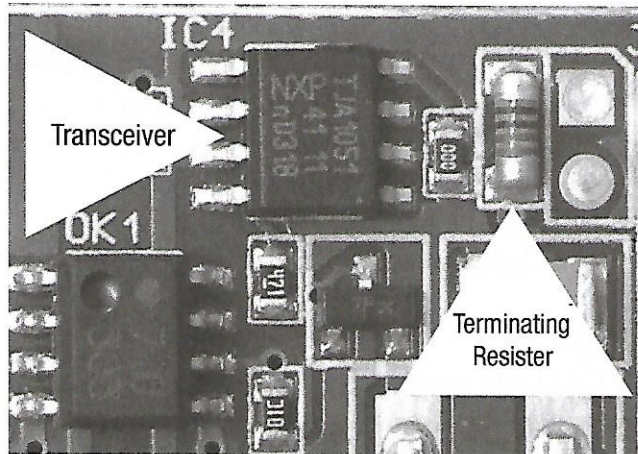


THE NETWORK continued...

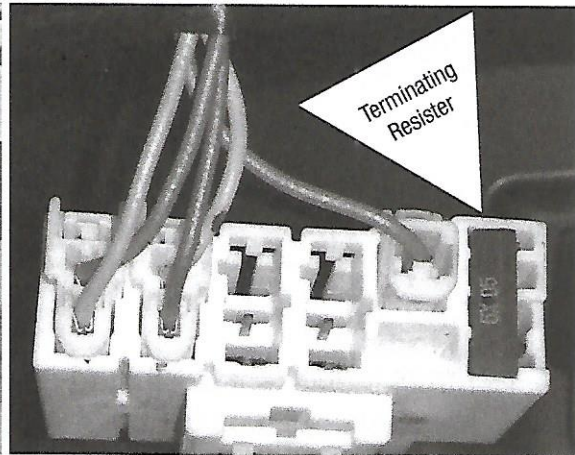
Terminating Resistors

Terminating Resistors are located at the ends of a CAN, they absorb the messages to stop them from continuing along the network. The function of absorbing the message is further explained under the "The Message" topic.

The vast majority of vehicles have the Terminating Resistor integrated into certain Nodes. These Nodes are called Terminating Nodes, while some vehicles have an standalone Terminating Resistor usually located in a Junction Connector.



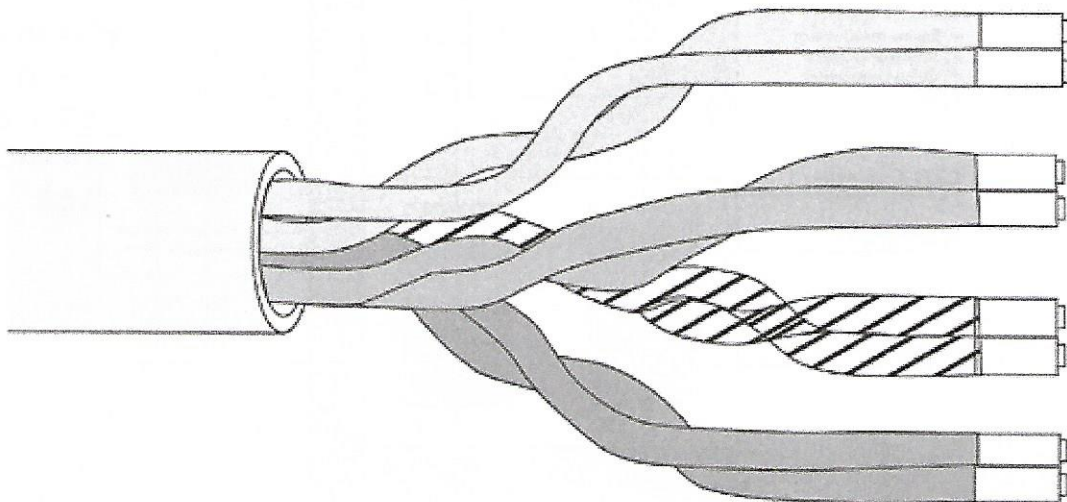
Terminating Node section of a PCB



Terminating Resistor in a Junction Connector

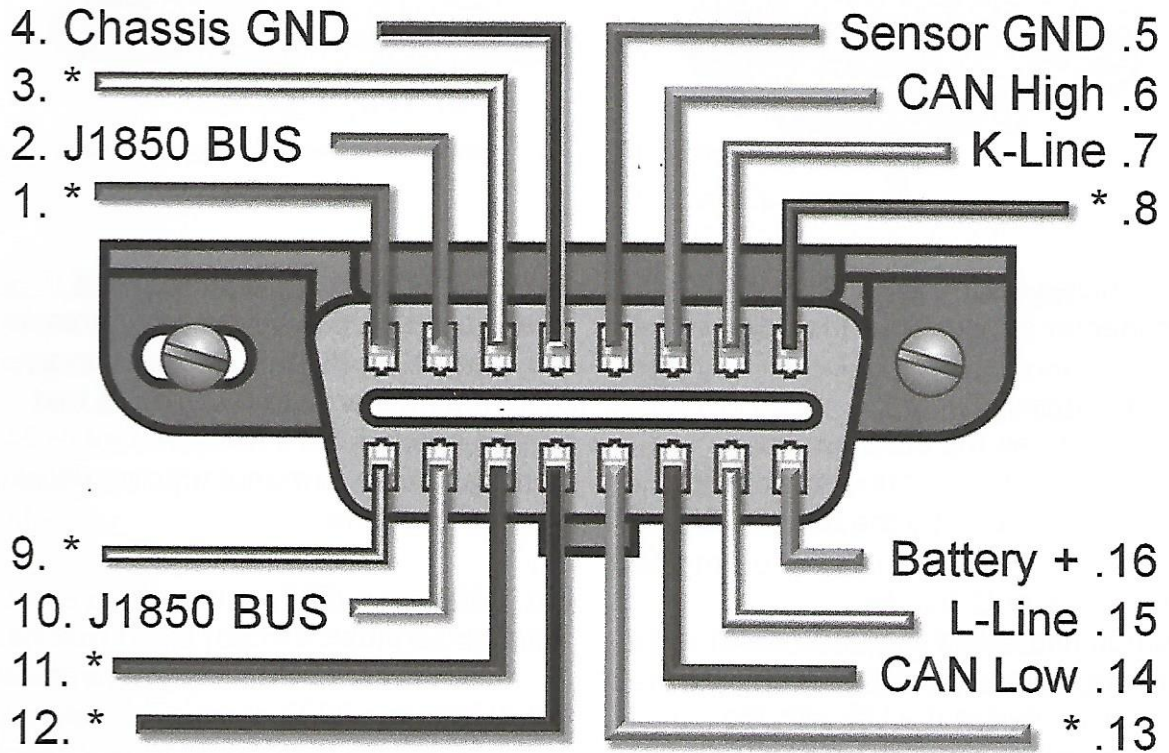
Wiring

The wiring circuit for the CAN consists of the two wires (CAN High and CAN Low) twisted together in what is called a twisted pair. In Automotive vehicles the method used to reduce Electro-Magnetic Interference (EMI) is to twist the wiring, this means that with every twist the EMI is reversed and therefore cancels itself out (Twisted Pair wiring was first invented in 1881 to overcome interference in telephone wires caused by the introduction of Electric Trams).

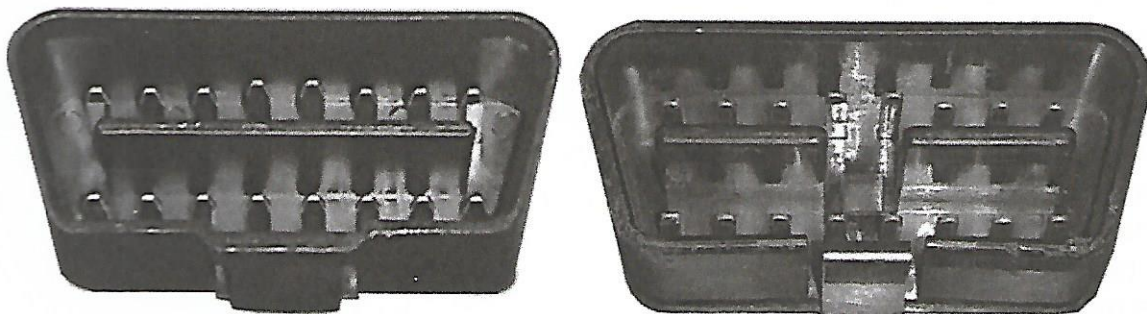


DIAGNOSTIC CONNECTOR

The Diagnostic Connector provides the link for a compatible Scan Tool to communicate with a vehicles control modules and is required to be within reach of the driver, generally below the steering column. Since the introduction of ADR79/01 this link is made using CAN Bus.



It should be noted that there are two types of the official SAE J1962 diagnostic connector:



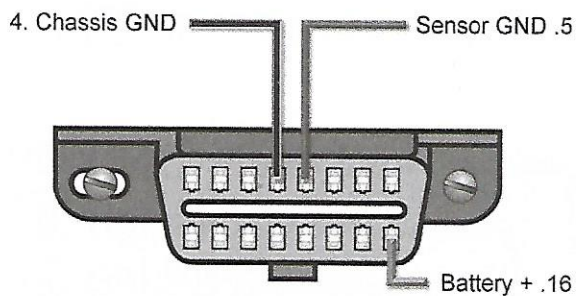
Type A - 12 Volts ONLY

Type B - 12 and 24 Volts compatible

Manufacturers are numbering wiring set falsely to confuse techs to bring vehicles back to manufacturers.

DIAGNOSTIC CONNECTOR continued...

Ground and Power circuits



All vehicles fitted with a 16 pin OBD Connector should have the following:

Pin 4: Chassis Ground

This has been the configuration standard for this connector since its recommendation by the SAE in 1988.

Pin 5: Sensor Ground

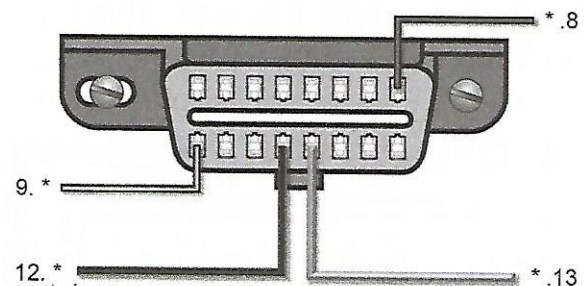
(sometimes called Signal Ground)

The requirement for this circuit was added in 1996 in the US with the implementation of OBD-II and 2001 in Europe with the implementation of the EURO-III standard. Unlike the Chassis Ground which is usually grounded to the nearest ground point to the connector, the Sensor Ground is grounded to the same ground point as the ECM.

While a lot of documentation states that you can test the ECM Ground at the OBD Connector this is NOT entirely correct as it does not allow for loss of ground between the ground point and ECM (damaged wiring) and most ECM's utilise multiple ground points.

Pin 16: Unswitched Battery Volts

Discretionary circuits - Part I



Pins 8, 9, 12 and 13: Discretionary

These can be used by manufactures as they see fit. As these are discretionary there are no standard basic tests that can be applied.

Some example of manufacturers utilising these circuits are:

Pin 8: Nissan <2005

Manual diagnosis switch

Pin 8: Nissan >2005

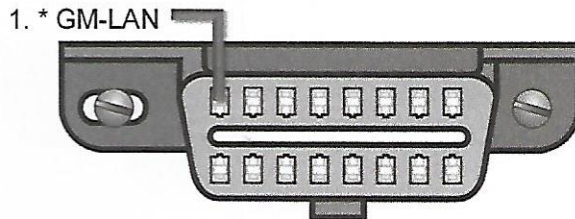
Ignition Voltage

Pin 13: Toyota

Manual diagnosis switch

DIAGNOSTIC CONNECTOR continued...

Discretionary circuits - Part II



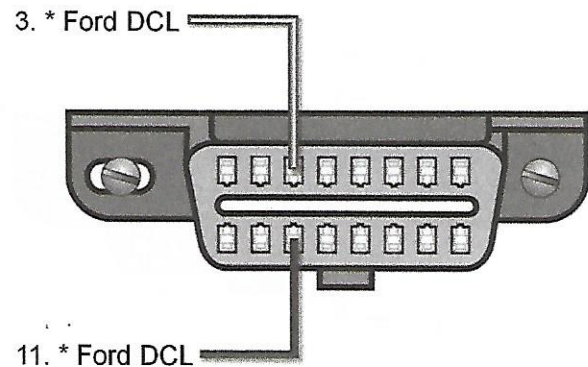
Pin 1: GM Low Speed LAN

Here is an example of a manufacturer using another discretionary circuit.

GM/Holden use Pin 1 for communication with their single wire the Low Speed Network.

As this is discretionary there are no standard basic tests that can be applied. However, the GM Low Speed LAN operates on a similar basis as the K-Line signal except it is reversed. It is a basic binary code, the idle voltage is 0 Volts with a signal voltage of Battery Volts.

Discretionary circuits - Part III



Pins 3 and 11: Ford DCL Network

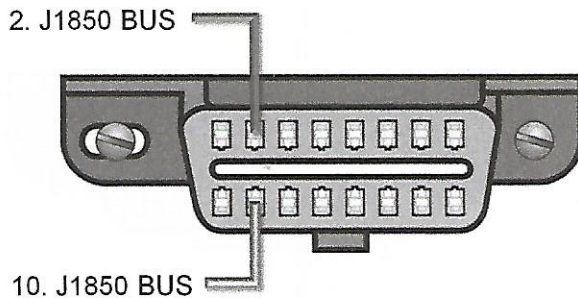
Here is another example of a manufacturer using a discretionary circuit.

Ford use Pins 3 and 11 for communication with their two-wire Medium Speed Network.

As this is discretionary there are no standard basic tests that can be applied. However, the Ford DCL Network is similar to CAN BUS in its configuration. Therefore the Resistance Test for CAN Bus is also appropriate for Ford's DCL Network.

DIAGNOSTIC CONNECTOR continued...

J1850 BUS circuits



There are 2 types of J1850 Networks:

Pin 2: SAE-J1850 VPW

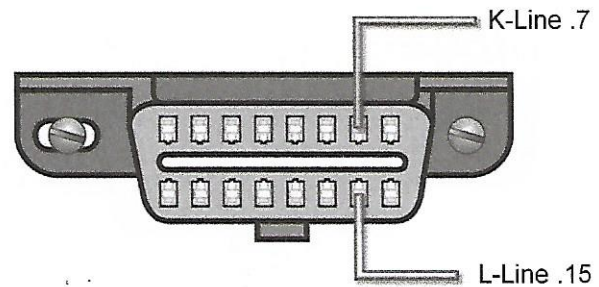
Used almost exclusively by GM in the US between 1996 & 2007 it is a single wire communication network (the only AU production vehicles to use this are the VY & VZ Gen. III V8's)

Pin 2 and 10: SAE-J1850 PWM

Used almost exclusively by Ford in the US between 1996 & 2007 it is a two wire communication network (the only AU production vehicles to use this are the AU series Falcon's)

The SAE-J1850 PWM was pretty much a precursor for CAN Bus. It has many of the same capabilities, however J1850 was only recognised by SAE in the US so when OBDII was updated in 2008 the ISO CAN Bus protocol was adopted because of its international compliance.

ISO9141 and KWP2000



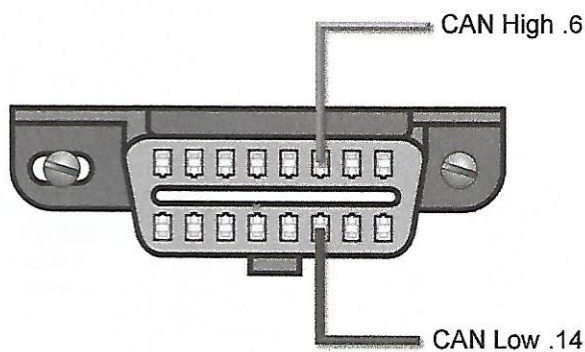
The ISO9141-2 & ISO14230-4 (KWP2000) protocols are most commonly known as the K-Line & L-Line. These are International Standard (ISO) protocols and were used for most pre-CAN Bus vehicles in Europe and Asia, as well as by the Chrysler group in the US. Therefore these are the most common pre-CAN Bus protocols in AU.

Pin 15: L-Line

In very early ISO9141-2 protocols Scan Tools used the L-Line to send a request to the ECM to create a Link with the Scan Tool. Then all of the communication was done via the K-Line.

Pin 7: K-Line

All other pre-CAN Bus ISO protocols do not require the L-Line and all communication is done on the K-Line (this is by far the most common pre-CAN Bus ISO configuration). The K-Line signal is a basic binary code, the idle voltage is Battery Volts (Binary 1) with a signal voltage of 0 Volts (Binary 0). The K-Line will not usually command a signal unless it is triggered to do so by a Scan Tool. The K-Line is of such basic design that is not able to communicate with multiple Nodes (Control Modules) simultaneously, it must connect with each node individually.

DIAGNOSTIC CONNECTOR continued...**CAN Bus circuit****Pins 6 and 14: CAN Bus**

The CAN Bus (Controller Area Network Bus) was developed by Bosch to fulfil its intra-vehicle communication needs. Although Bosch started on CAN Bus in 1983 and completed V1.0 in 1986 it wasn't until 2001 that it started to gain popularity.

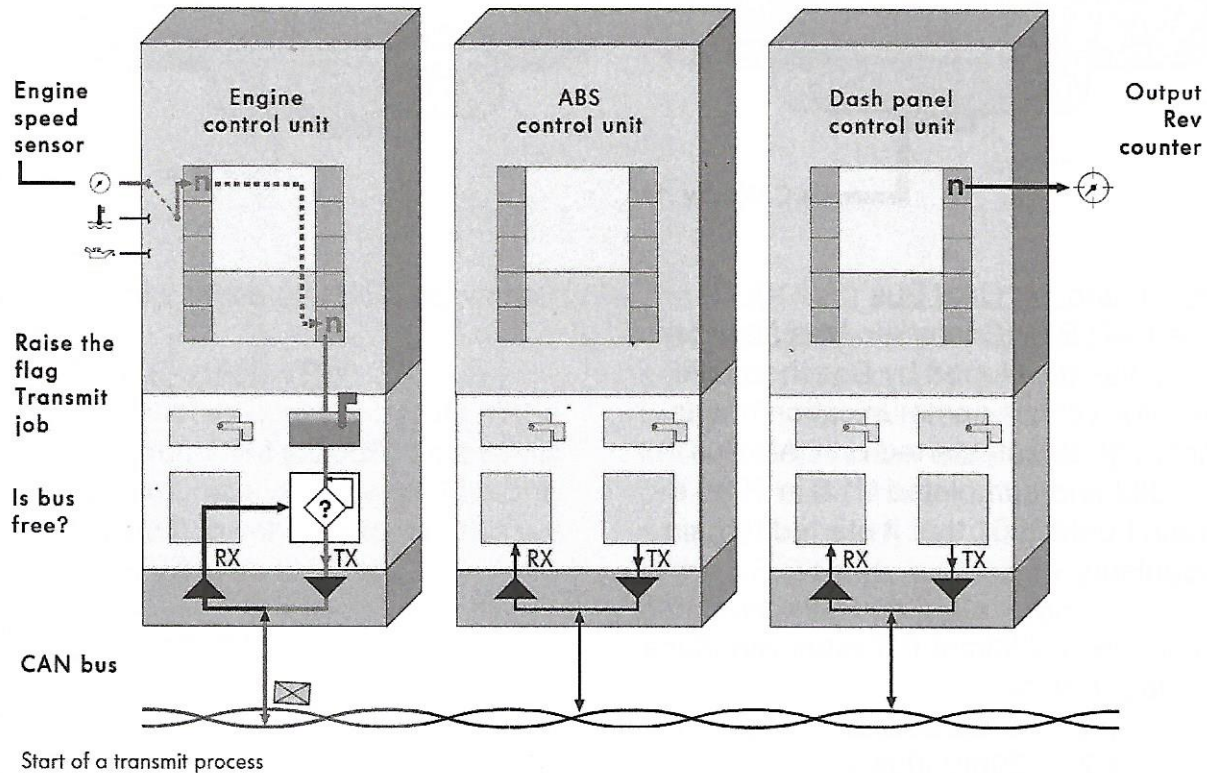
There are 4 different BIT-rates variations in the protocol:

- | | |
|-----|-------------|
| 1.1 | 11bit/500Kb |
| 1.2 | 29bit/500Kb |
| 1.3 | 11bit/250Kb |
| 1.4 | 29bit/250Kb |

THE MESSAGE

The process of sending and receiving CAN messages is best described using the following diagrams:

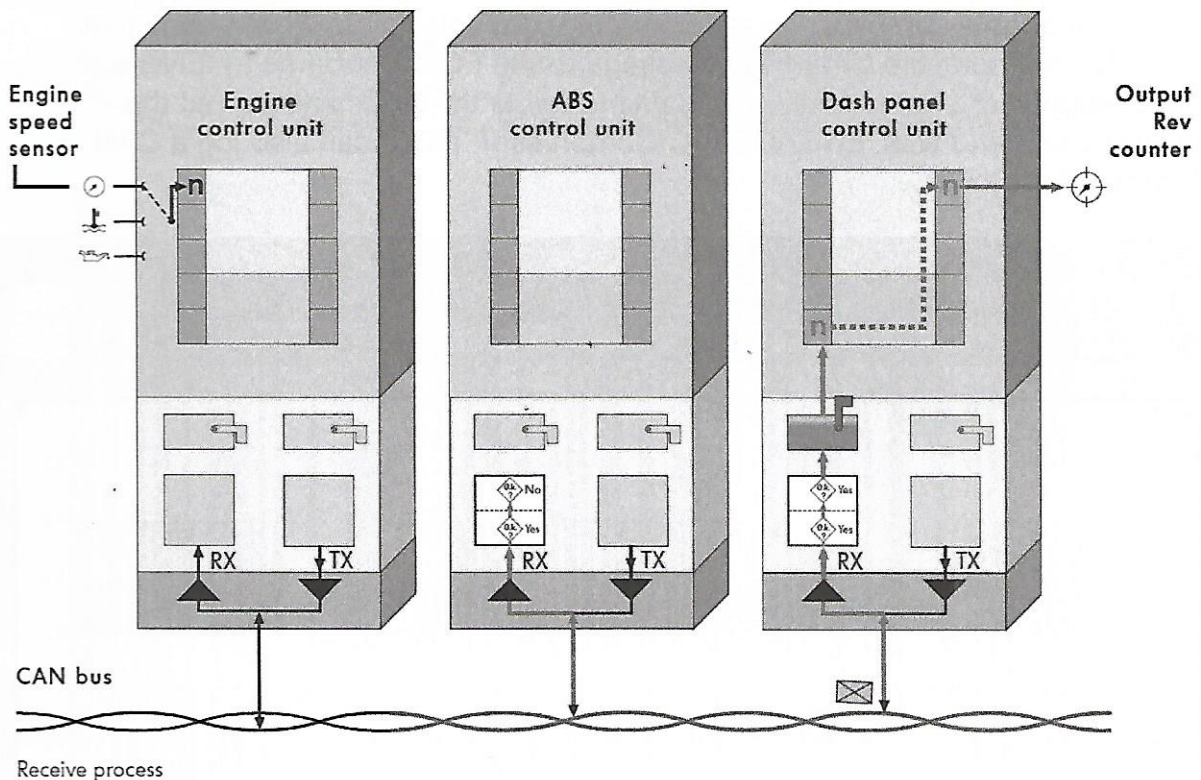
Sending



1. Engine speed (n) is received as an input at the ECU
2. The voltage waveform is processed by the ECU
3. The ECU outputs the value 'n' in the form of a digital message
4. The CAN Controller adds details such as origin, priority and checksum
5. The message is placed in the outgoing mailbox
6. The CAN Controller waits for a free space on the CAN Bus
7. Once a space is found the Transceiver sends the message.

THE MESSAGE continued...

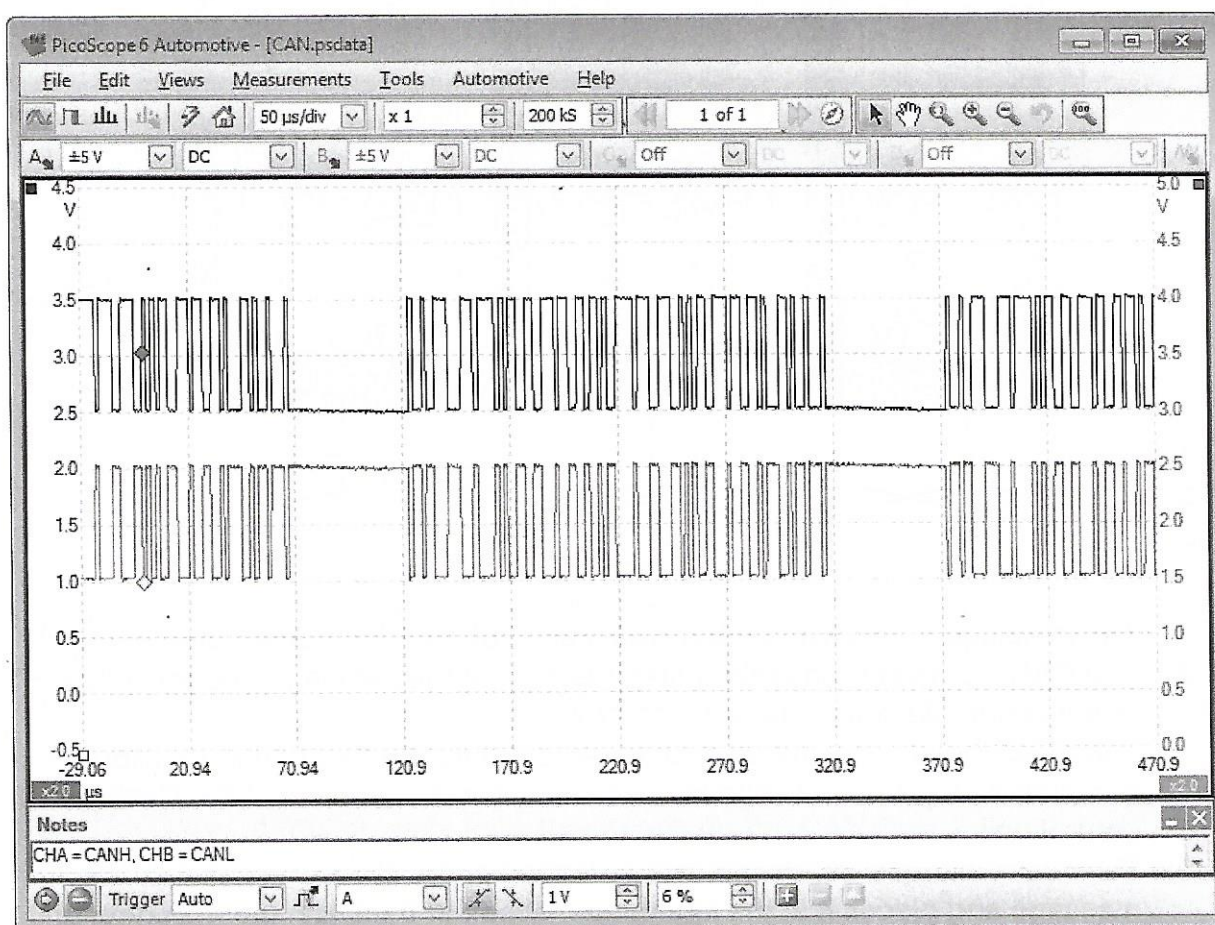
Receiving



1. The message is received by the Transceiver of the ABS control unit
2. The CAN Controller reads the categorisation of the message and identifies that it is not relevant to the ABS control unit
3. The message is not forwarded to the ABS control unit's incoming mailbox
4. Simultaneously, the message is received by the Transceiver of the Dash panel control unit
5. The CAN Controller reads the categorisation of the message, accepts the message and places it in the incoming mailbox of the Dash panel control unit
6. The Dash panel control unit processes the data and outputs a voltage waveform that controls the Tachometer (Rev counter).

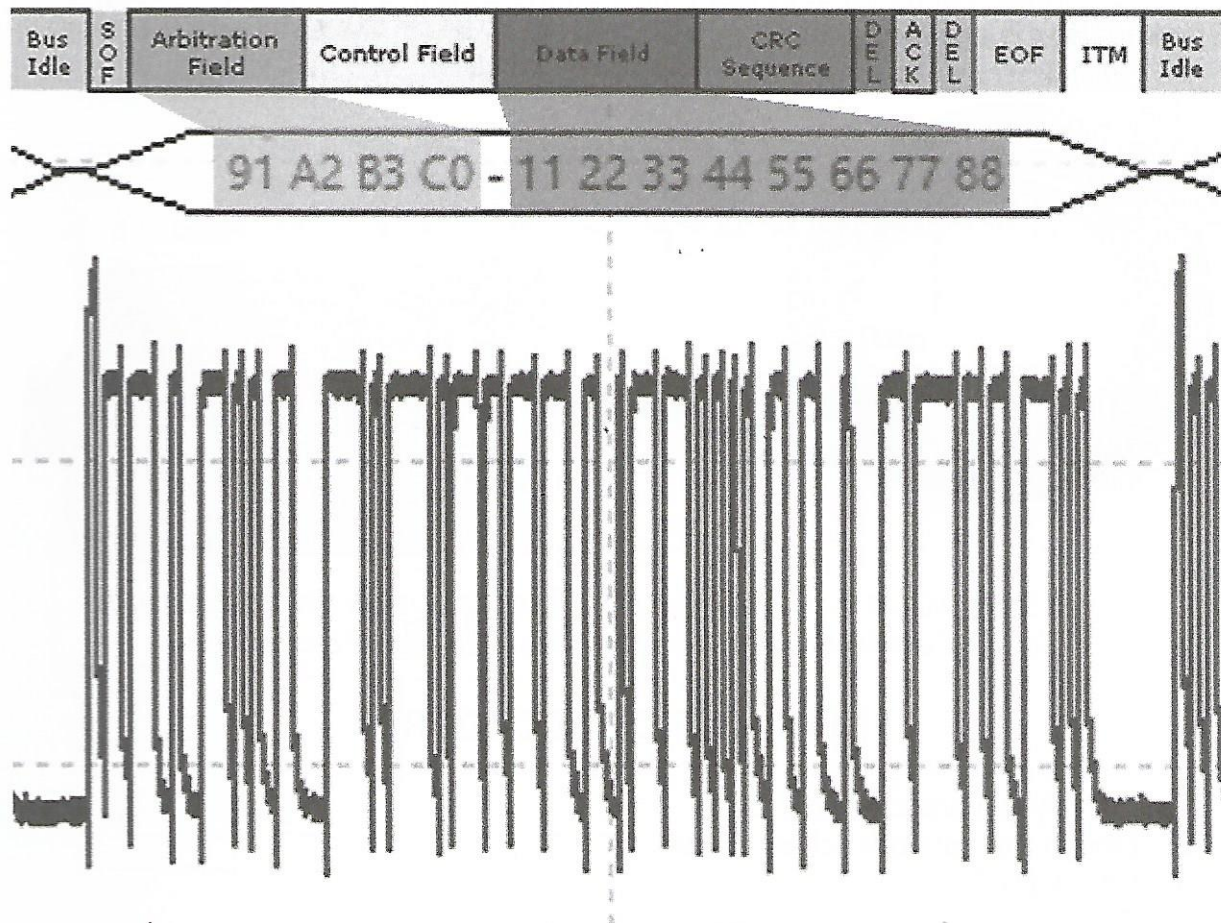
THE MESSAGE continued...

The CAN BUS protocol uses 2 signals that are a perfect mirror image of each other. In automotive vehicles, messages are sent simultaneously down two communication lines (CAN-High & CAN-Low). This allows Nodes to identify corrupted messages on the network and act upon them. When a corruption to a CAN message occurs it does not convert the complex message into a different readable complex message, it makes it unintelligible. This means that when (for example) the CAN-High message to the ECM translates to 'ENGAGE A/C Compressor' yet the CAN-Low is unintelligible the Node knows that the desired command was 'ENGAGE A/C Compressor' and it can also log a CAN Communication DTC.



THE MESSAGE continued...

The following image provides a graphical representation of how the CAN Controller decodes a CAN signal into a serial data message:



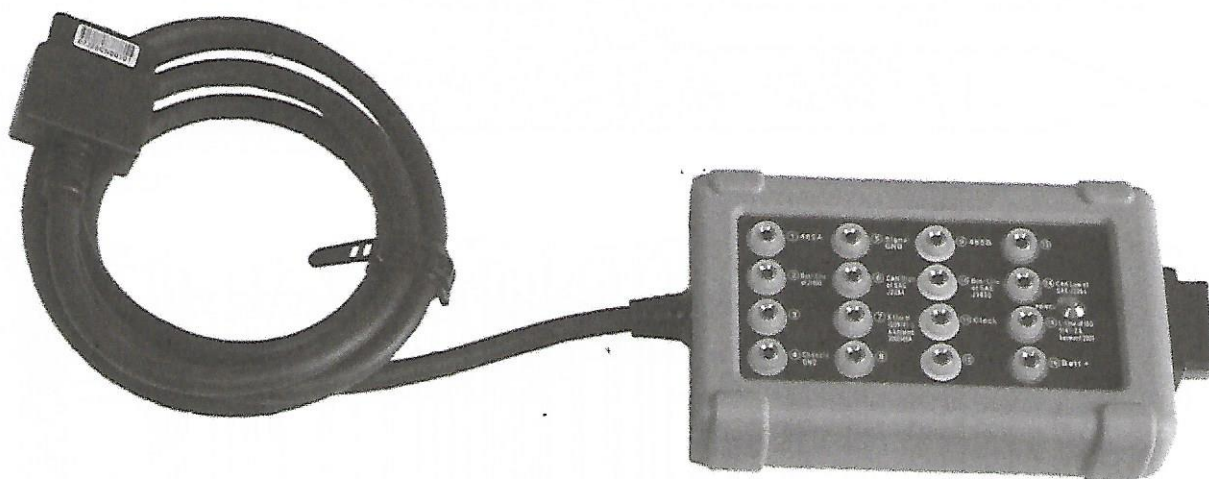
Decoding software such as that provided with the Pico Automotive Scope focuses on two fields:

- Arbitration Field - This is the identifier which also includes the priority
- Data Field - the data field is the only field that has a variable length and can contain up to 64 bits, this field includes the main message

The CAN serial data message and decoding is significantly more complex than the basic example provided above, this will be explored further in future clinics.

ACCESSING THE DATA

While the Diagnostic Link Connector (DLC) is the obvious connection point, it should only be used with an official SAE J1962 male connector to avoid spreading of the terminals. If carrying out diagnostics on the DLC it is recommended that a Breakout Box is utilised.



Breakout Boxes such as the Pico CAN Test Box offer a pass through connector so that the Scan Tool can be used at the same time as a multimeter or oscilloscope!

DIAGNOSTIC PROCEDURE

1. Identify issue/complaint
2. Obtain the network schematic/s
3. Check DTC's
4. Check data transfer with Breakout Box or Scan Tool
5. Check resistance between terminals 6 & 14
6. Check voltage between terminals 6 & 14
7. Check for short to ground at terminals 6 & 14
8. Function Test - Check message sent in Scan Tool Data
9. Function Test - Check carry out command with Scan Tool Actuation
10. Check waveforms with an Oscilloscope

Identify issue/complaint

The first step in any diagnosis is witnessing the fault.

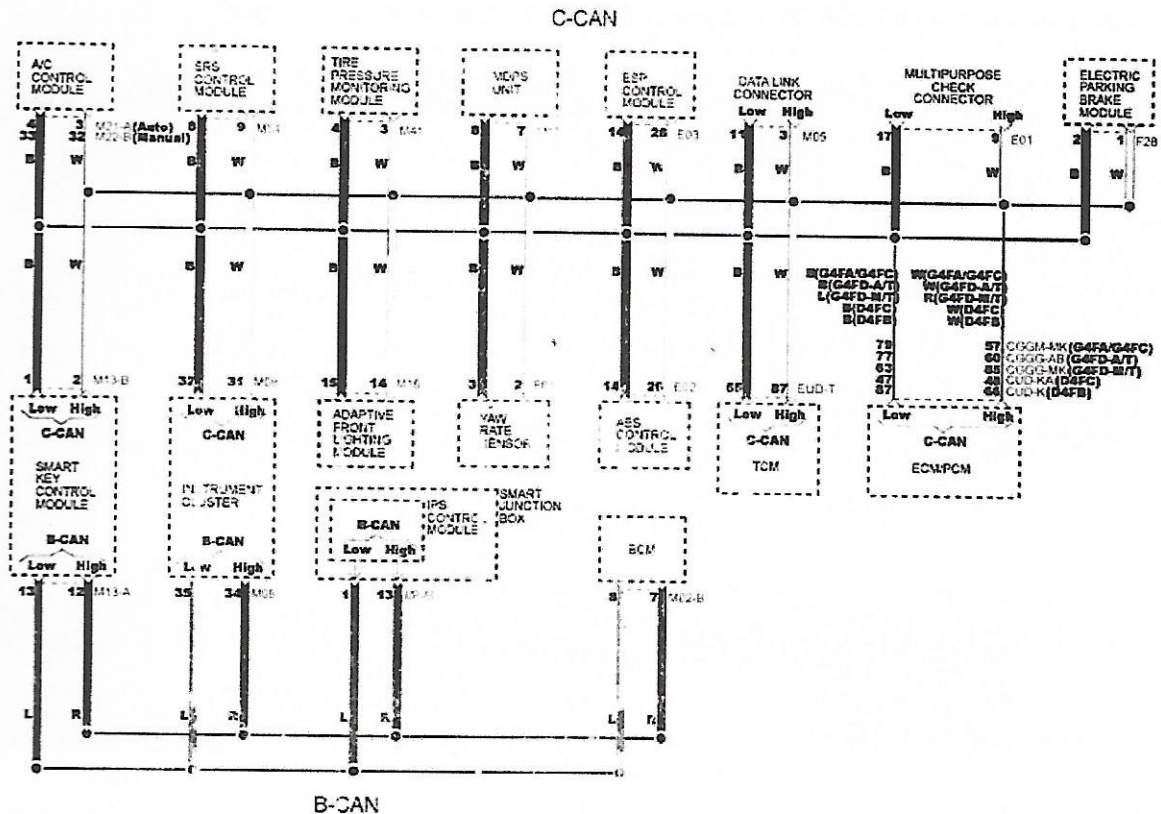
You'll need to know when the fault occurs and if possible how to make it fault.

Better still, have the driver of the vehicle show you the fault!

DIAGNOSTIC PROCEDURE continued...

Obtain the network schematic/s

The best way of obtaining an understanding of the CAN Bus is to review the schematic diagram. In the following example for an Hyundai i30 there are a number of factors evident that will assist in the diagnostic process:



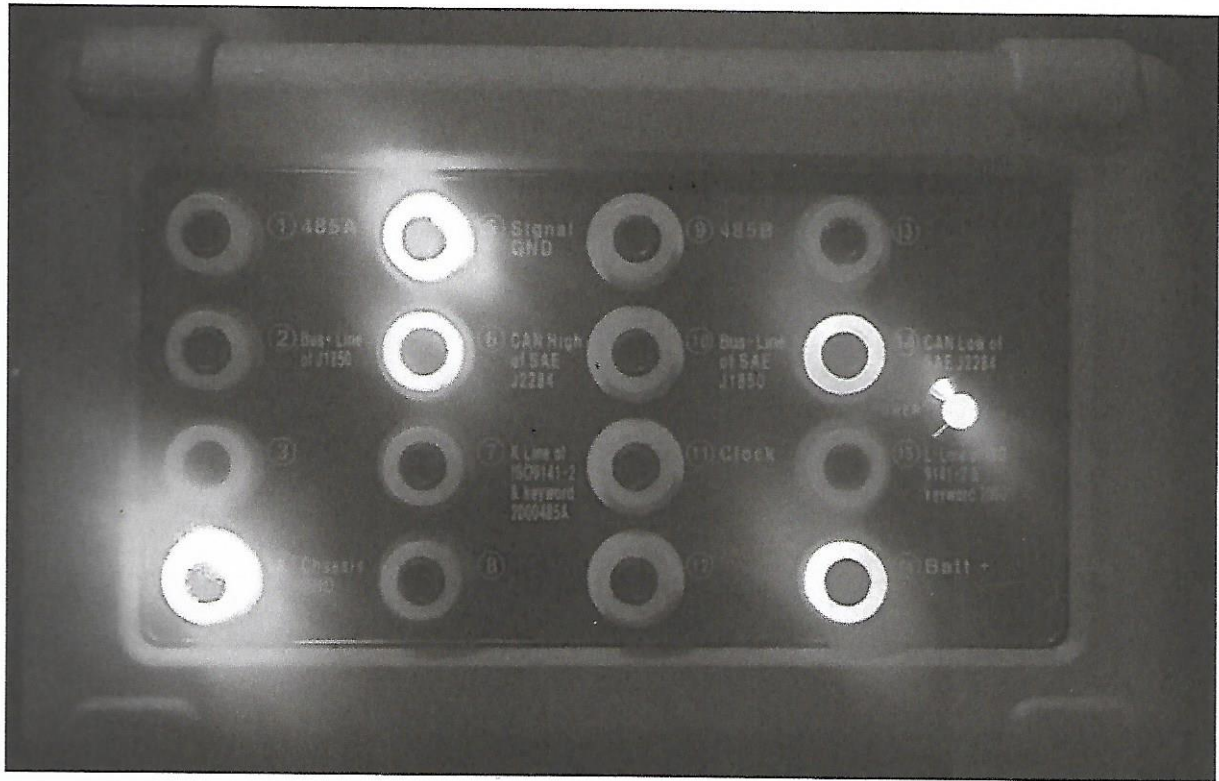
- There are two CAN's
C-CAN is the primary network (identified by the location of the DLC)
B-CAN is the secondary network
- The DLC states that CAN Low is at Pin 11 and CAN High is at Pin 3
A check of the DLC diagram shows that Hyundai reverse the numbering sequence and the typical pins are used
- The configuration of the networks is of a parallel format
- Both the Instrument Cluster and the Smart Key Control Module communicate on both networks, the written description of the CAN confirmed that the Instrument Cluster is the Gateway Module.

Another example is provided back on page 4, the example from a VF Commodore shows a Series configuration and the resistors that create the Terminating Nodes.

DIAGNOSTIC PROCEDURE continued...

Check data transfer with Breakout Box or Scan Tool

If you are using a Breakout Box on the DLC these will usually include LED confirmation lights. If equipped these will provide an immediate confirmation of the networks that are communicating with the DLC.



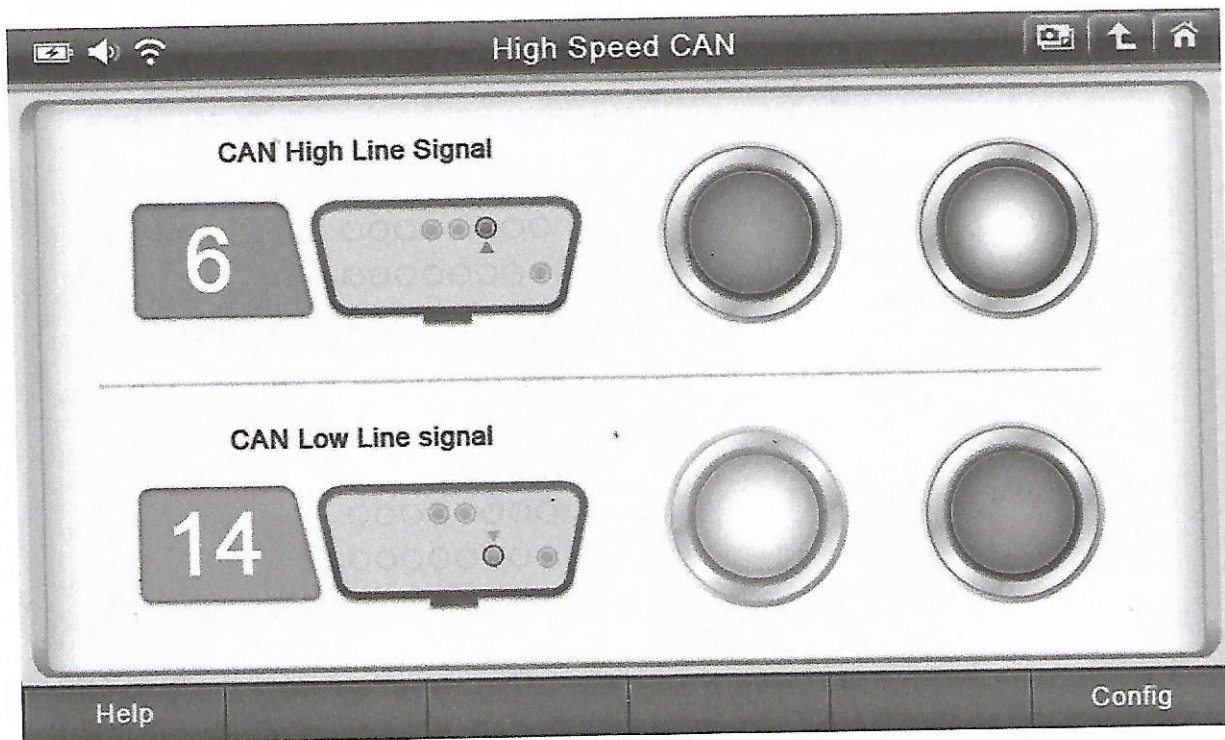
In the image above the confirmation LED's are visible for:

- Pin 4 - Chassis GND
- Pin 5 - Signal GND
- Pin 6 - CAN High
- Pin 14 - CAN Low
- Pin 16 - Batt+

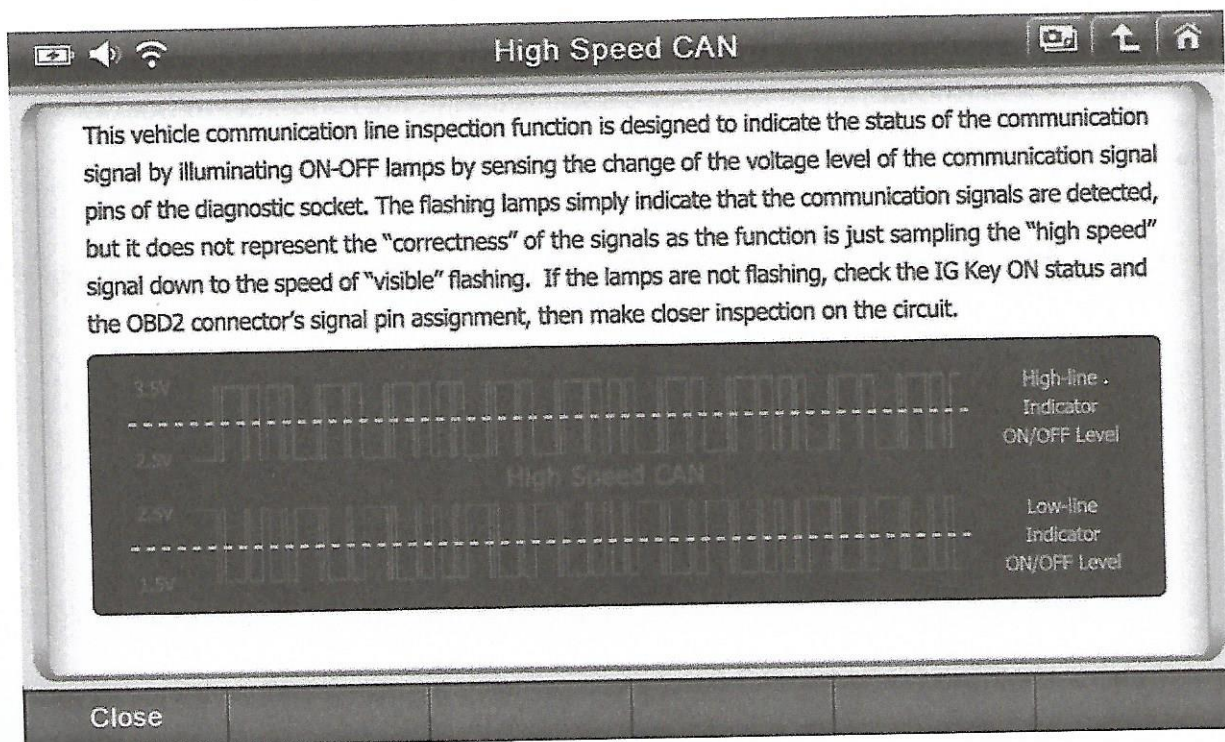
* Don't use the led lights on breakout boxes use a meter

DIAGNOSTIC PROCEDURE continued...

If you do not have a Breakout Box with confirmation lights it is possible to do a network check with some Scan Tools. The following image is from the G-Scan2:



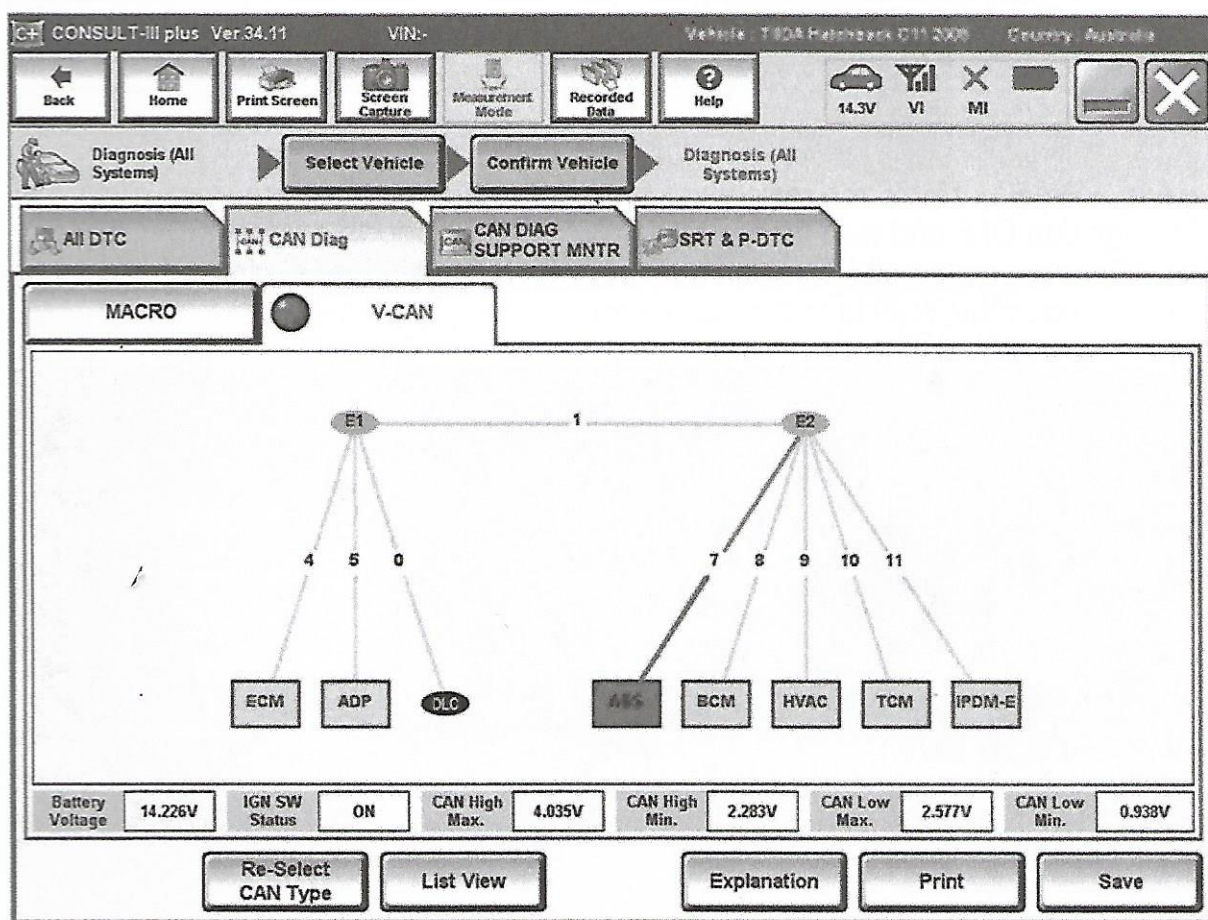
Tools such as the G-Scan2 only display the status of the CAN Voltages measured at the DLC. This means that if the CAN Bus is intact between the two Terminating Resistors and the DLC then any faults will not be identified. The following image describes the function of the CAN Signal Indicator.



DIAGNOSTIC PROCEDURE continued...

Some original equipment (OE) dealer tools have a much greater level of functionality, such as the Nissan Consult-III Plus which includes a CAN Diagnosis function.

The Scan Tool sends a message to each Node and waits for a response. Using a combination of vehicle specifications that are loaded into the tool and the responses received off of the CAN the Scan Tool builds a graphical representation of the vehicle network, highlighting functioning sections in green and nonresponsive Nodes in red.



In this example the Nissan Consult-III Plus Scan Tool has identified an issue with the network connection to the ABS Module.

Unfortunately this level of functionality is reserved for OE Scan Tools.

Testing
Key off & 15 meters from car.
let sit for min 15mins

DIAGNOSTIC PROCEDURE continued...

* $60\Omega \pm 3\Omega$

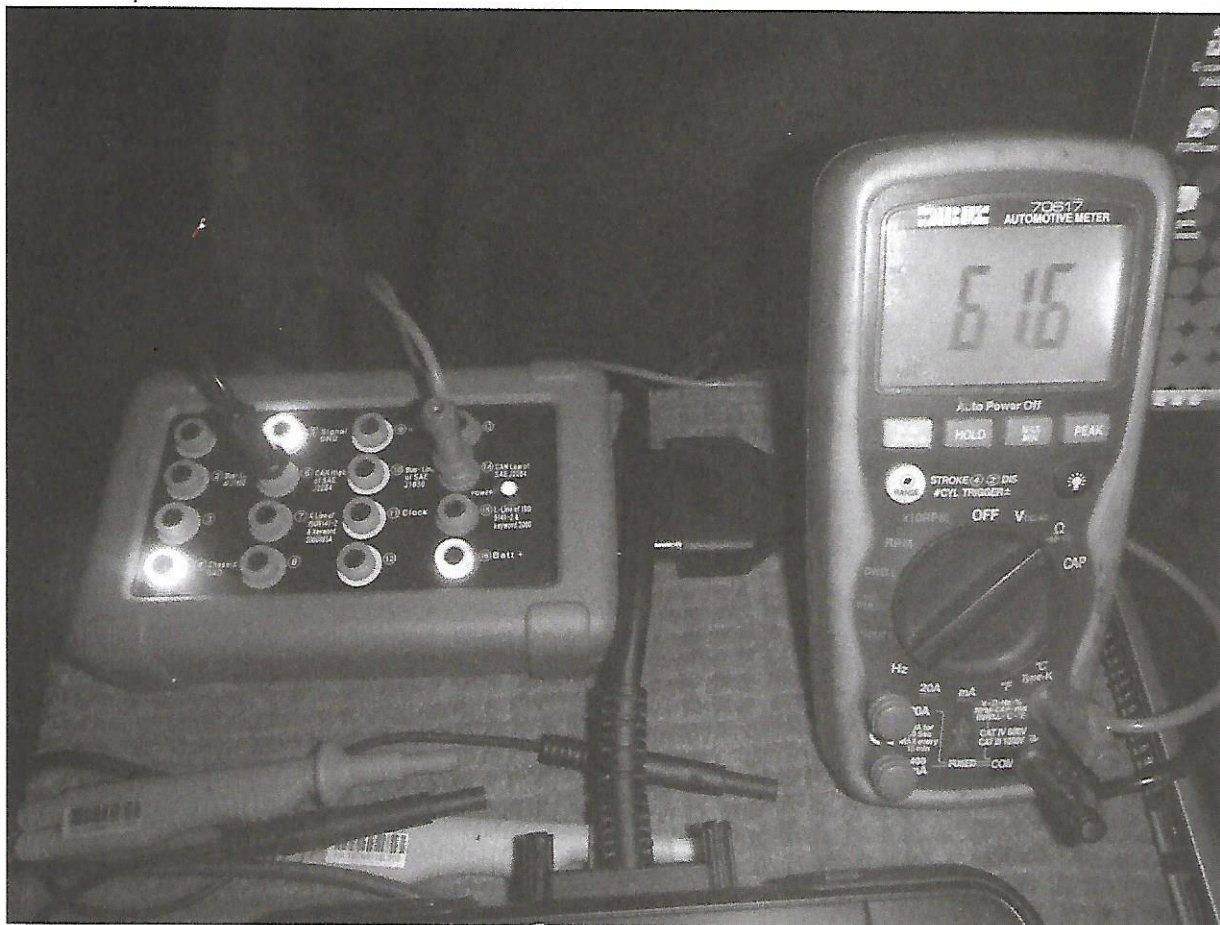
Check resistance between terminals 6 & 14

Checking the resistance across the CAN-High (Pin 6) and CAN-Low (Pin 14) circuit at the DLC provides a quick check of the CAN Bus integrity. The result should be within 15% of 60Ω . The following table provides outcomes and possible causes:

Result	Condition
51 to 69Ω	Normal
$<51\Omega$	Short Circuit
70 to 102Ω	High Resistance
102 to 138Ω	Open Circuit
∞ (Infinite Ohms)	Multiple Open Circuits

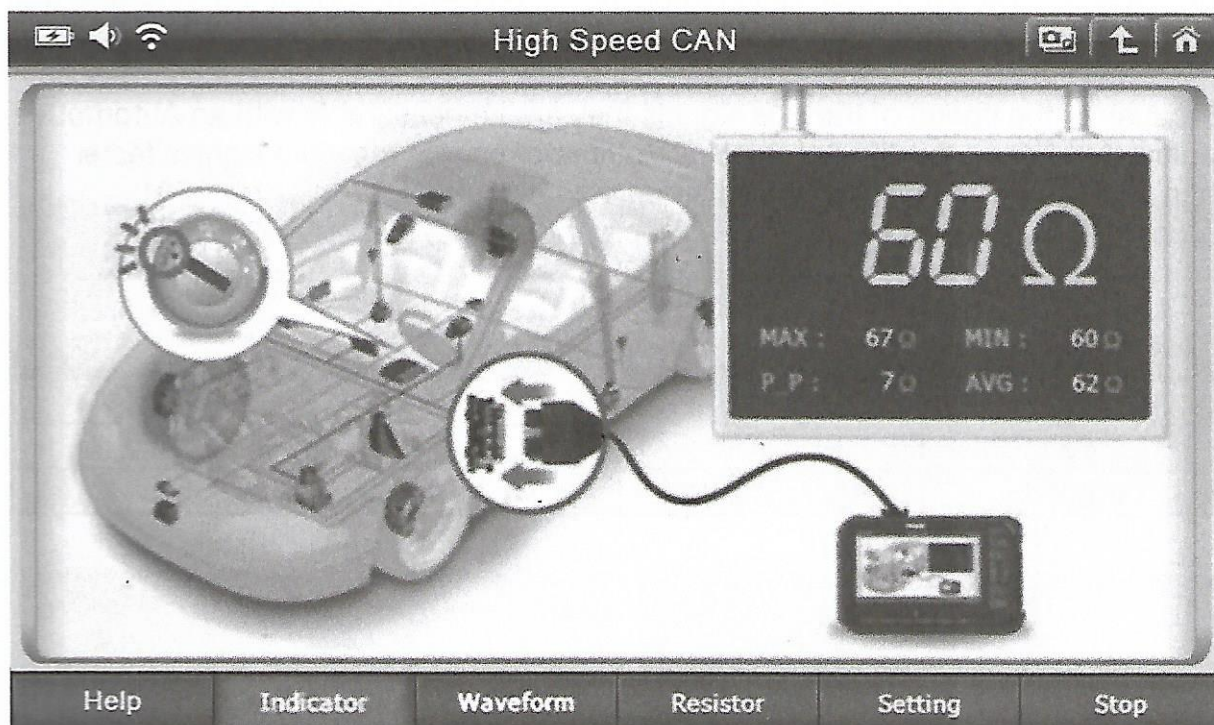
If using a Breakout Box, the resistance check is a quick and easy process:

1. Ignition OFF and wait for modules to enter sleep mode or disconnect battery
2. Connect multimeter in resistance test with leads across terminals 6 and 14
3. Compare the results to the table above

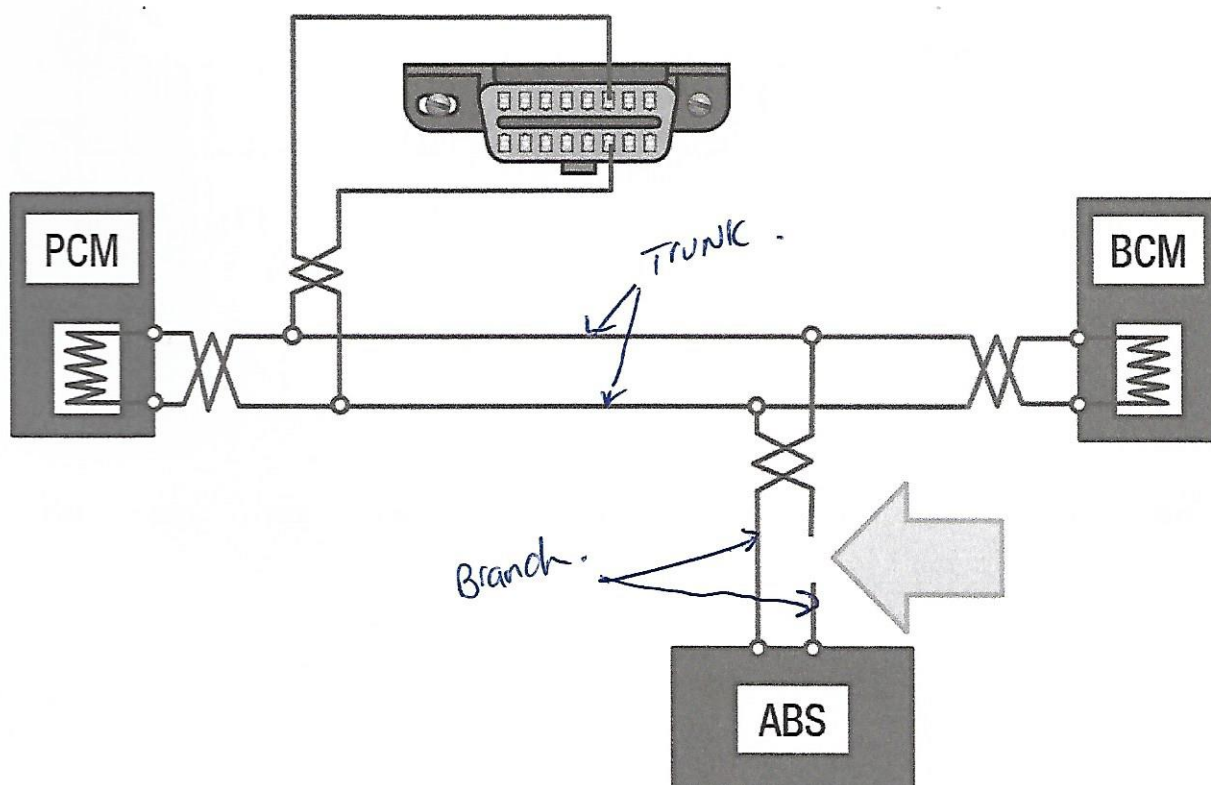


DIAGNOSTIC PROCEDURE continued...

Some Scan Tools may also include this function. The following example is from the G-Scan2 with the optional VMI kit:



It should be noted that a resistance test cannot identify all CAN Bus infrastructure failures. The following example shows how an open circuit on a sub-branch of the network will not affect the resistance:



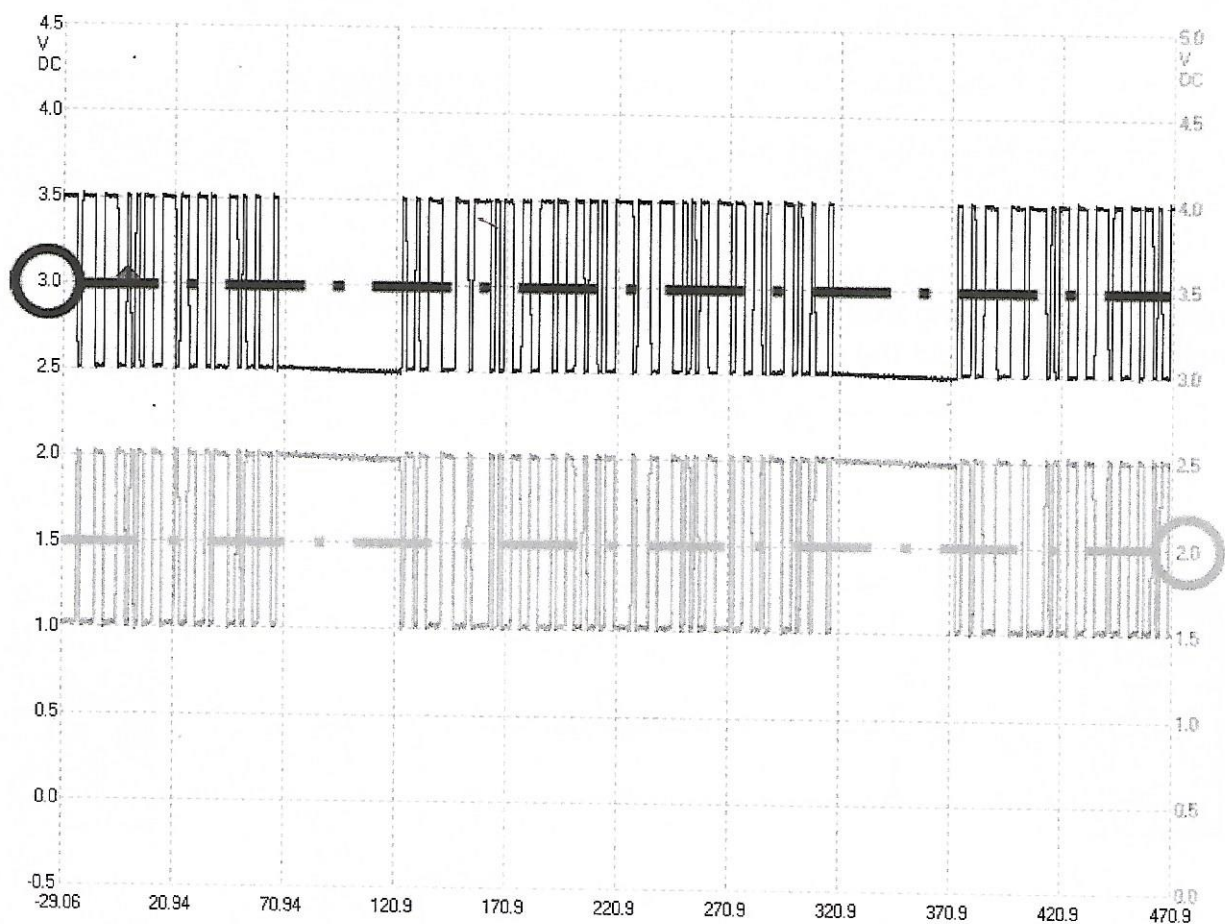
DIAGNOSTIC PROCEDURE continued...

Check voltage between terminals 6 & 14

Checking the CAN Bus voltage at the DLC checks how the Nodes (Control Modules) are using the network (as opposed to the resistance test that checked the integrity of the network).

Because of the speed of the Bus signals they are immeasurable with an Automotive Multimeter. Even a quality Automotive Multimeter cannot measure signals faster than 1mS (0.001 Seconds). CAN Bus operates as quickly as 1 μ S (0.000001 Seconds). This is why the Multimeter display shows the average voltage as indicated by the centre-line on the CAN BUS Scope patterns, see below:

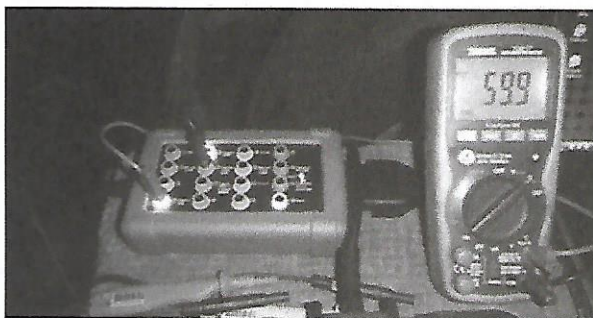
DLC Pins	Test	Result	Condition
4 and 6	Voltage	$\approx 3.0V$	Normal
4 and 14		$\approx 2.0V$	Normal
6 and 14	Differential Voltage	$\approx 1.0V$	Normal



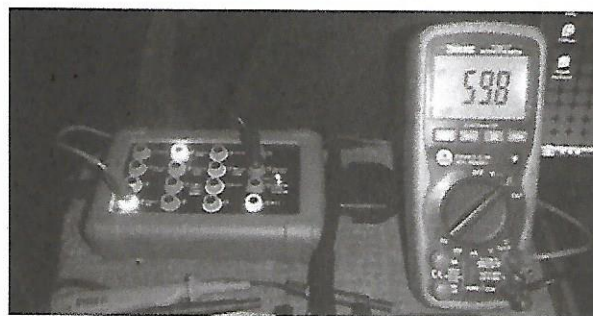
DIAGNOSTIC PROCEDURE continued...**Check for short to ground at terminals 6 & 14**

Because CAN Bus uses a floating ground (not grounded to the chassis of the vehicle), a short to ground will not alter the CAN resistance. A very easy check is to measure the resistance between the pins 6 and 14 to the ground pin/s of the DLC. The example below shows the testing of all 4 combinations (all values in kΩ):

Terminals 4 & 6



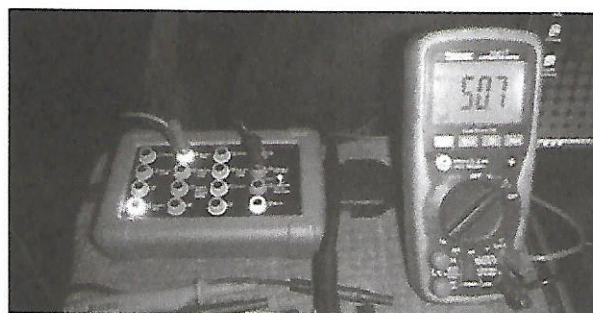
Terminals 4 & 14



Terminals 5 & 6



Terminals 5 & 14

**Note:**

Early CAN vehicles (1988 to 2005) quite often used shielded twisted pair wiring, as the shield was grounded it made these vehicles more susceptible to short to ground failures if the harness suffered an impact!

6 to Batt Post = 60Ω
 14 to Batt Post = 60Ω } good test.

DIAGNOSTIC PROCEDURE continued...

Function Test - Check message sent in Scan Tool Data

Monitor the data tables for values that are known to originate from another Control Module on the CAN Bus. An easy example that is relevant to most vehicles is the Vehicle Speed value that originates at the ABS Control Module:

▶ PCM(PowerTrain Control Module) > Data Analysis(All Items)					
Item	Value	Unit	Min	Max	
RPM	2043.00	rpm	0.00	2067.00	▲
Desired Idle Speed RPM	729.00	rpm	729.00	740.00	
Security Access Delay Time	10	s	10	10	
Desired SEGRP Valve Position	4.31	%	0.00	18.43	
Starter Enable High Side	Desable		-	-	
Starter Enable Low Side	Desable		-	-	
Sump Oil Temperature - Meas...	81	°C	64	81	
Key Power Voltage	13.87	V	10.87	13.99	
Requested torque Output of t...	10	%	0	48	
Reference Voltage	1.00	V	1.00	1.00	
Sensor Supply Voltage B	1.00	V	1.00	1.00	
Vehicle Speed	29	km/h	0	31	▼
Function Normal Graph Record Select Item					

Function Test - Check carry out command with Scan Tool Actuation

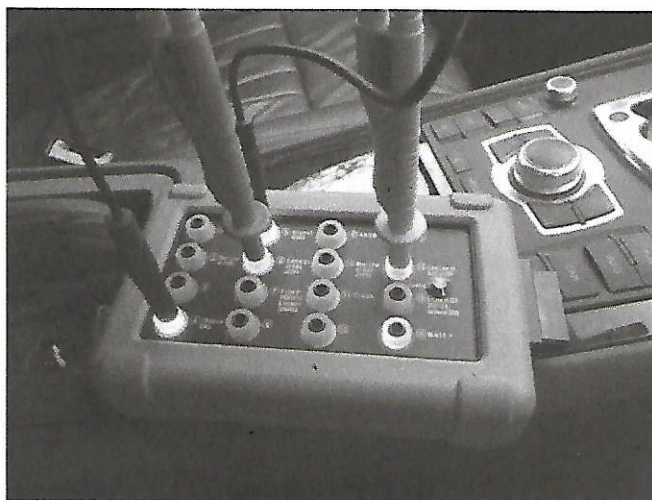
Actuation tests also prove CAN function. If for example a suspected fault exists with the CAN connection to the BCM, try using the Scan Tool to trigger the door lock actuators. If they cycle CAN is presently functioning.

Scope test ~~with~~ CAN Bus while commanding

DIAGNOSTIC PROCEDURE continued...

Check waveforms with an Oscilloscope

Oscilloscopes provide the ability to delve much deeper into CAN Bus diagnosis as well as expedite many or all of the multimeter based tests. Connecting a scope to the DLC is much easier with a Breakout Box:

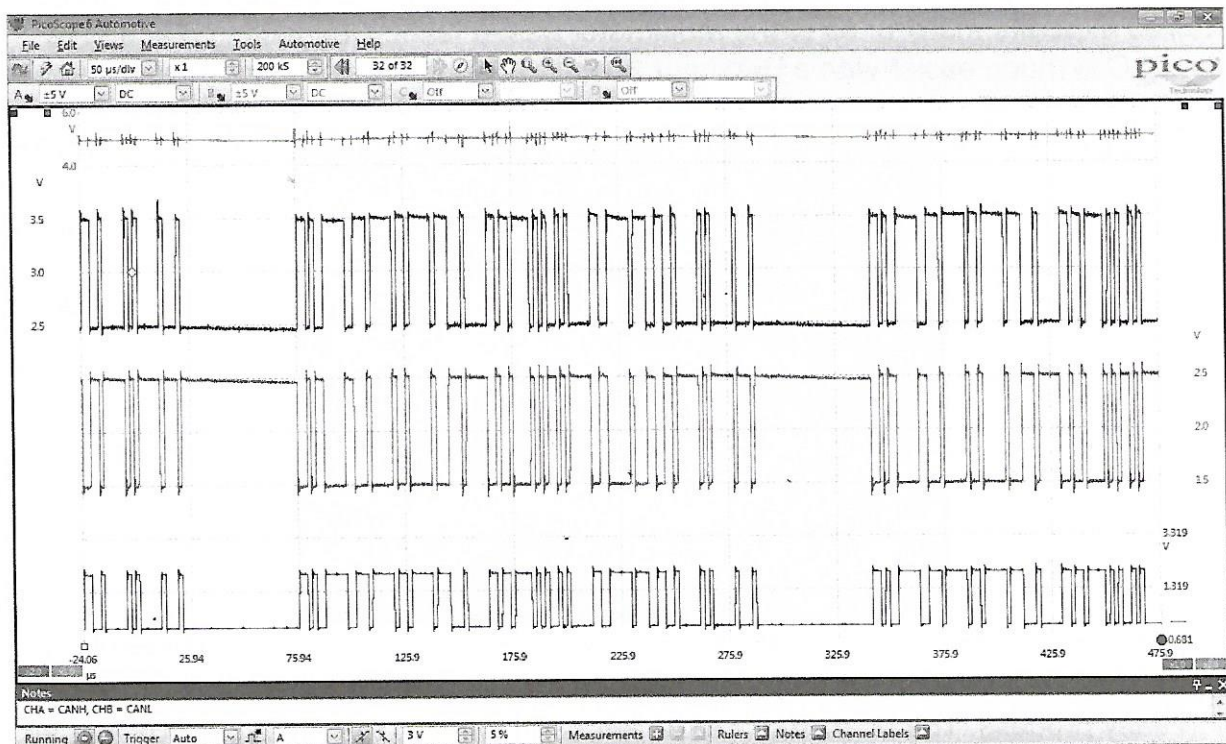


A well organised diagnostic cabinet makes connecting a scope to a vehicle a quick and easy process. The Scan Tool can be left connected to the Breakout Box and all of the diagnostic leads and probes are within arms reach:



WAVEFORM EXAMPLES

Normal CAN signal with Math Channels



*Math Channel A + B is the upper waveform on the adjacent left side scale
 CAN High is the upper centre waveform on the adjacent left side scale
 CAN Low is the lower centre waveform on the adjacent right side scale
 Math Channel A - B is the lower waveform on the adjacent right side scale*

Math channels are a calculated scope pattern based on an equation, for this example there are 2 basic equations:

A + B (the top waveform)

- The average of A + B should always be 5 Volts
- This feature provides an easy way to identify errors in the message, if the waveform deviates from 5 Volts an error has occurred

A - B (the bottom waveform)

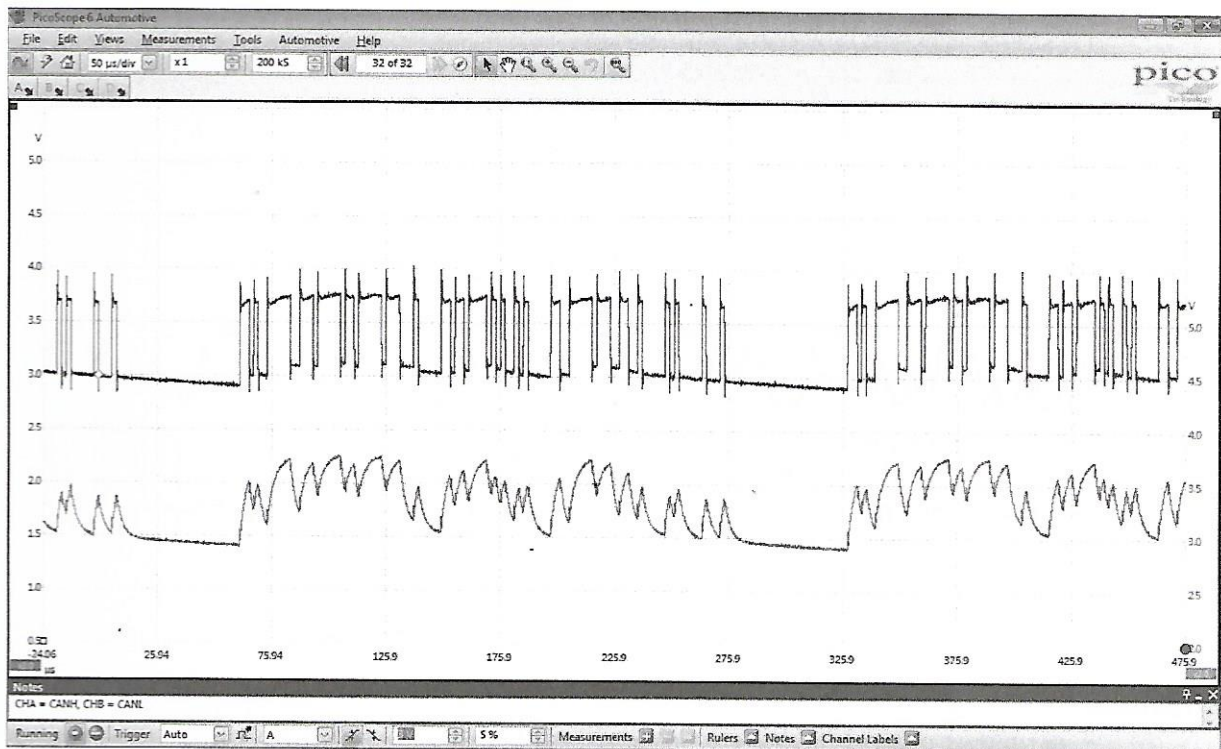
- The average of A - B should always be a 0 to 2 Volts waveform
- This feature can be helpful in cleaning up static from the waveform

*Data on CAN Bus Alters frequency when info is put on.
 Nodes affect the voltage (corrupts).*

**Can High & low Add together will always add up to 5volts
 if not you have a node problem in a module.*

WAVEFORM EXAMPLES continued...

CAN Low OPEN Circuit

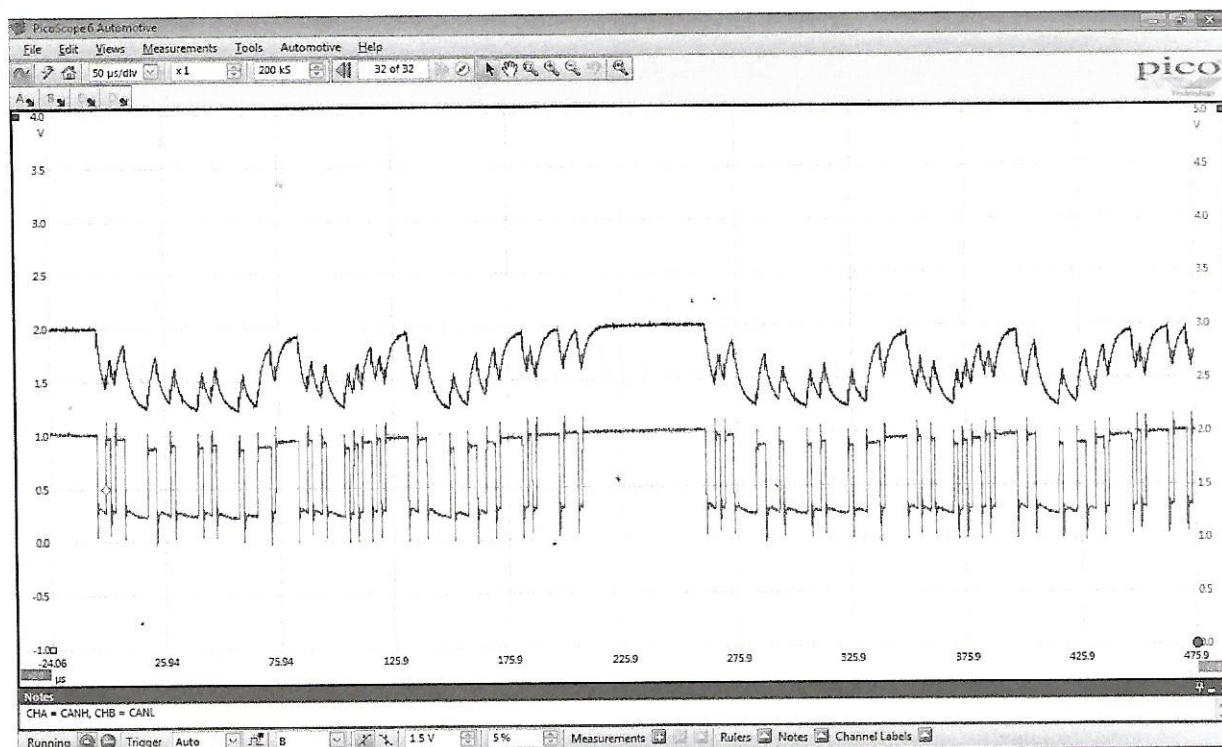


*CAN High is the upper waveform on the left side scale
CAN Low is the lower waveform on the right side scale*

CAN Bus uses a floating ground. This means that the ground circuit for the Transceivers is not connected to the chassis of the vehicle. The purpose of this design is that all Nodes do not require a common ground point and helps to isolate the circuit from interference. However, it also causes a fault on one side of the CAN Bus to cause a 'shift' on the other side of the circuit. This is evident on almost all CAN Bus faults. In this image you can see that the OPEN circuit on the CAN-Low has caused the CAN-High, OFF (IDLE) voltage to 'shift' from 2.5 Volts to 3.0 Volts. There is no fault on the high side.

WAVEFORM EXAMPLES continued...

CAN High OPEN Circuit

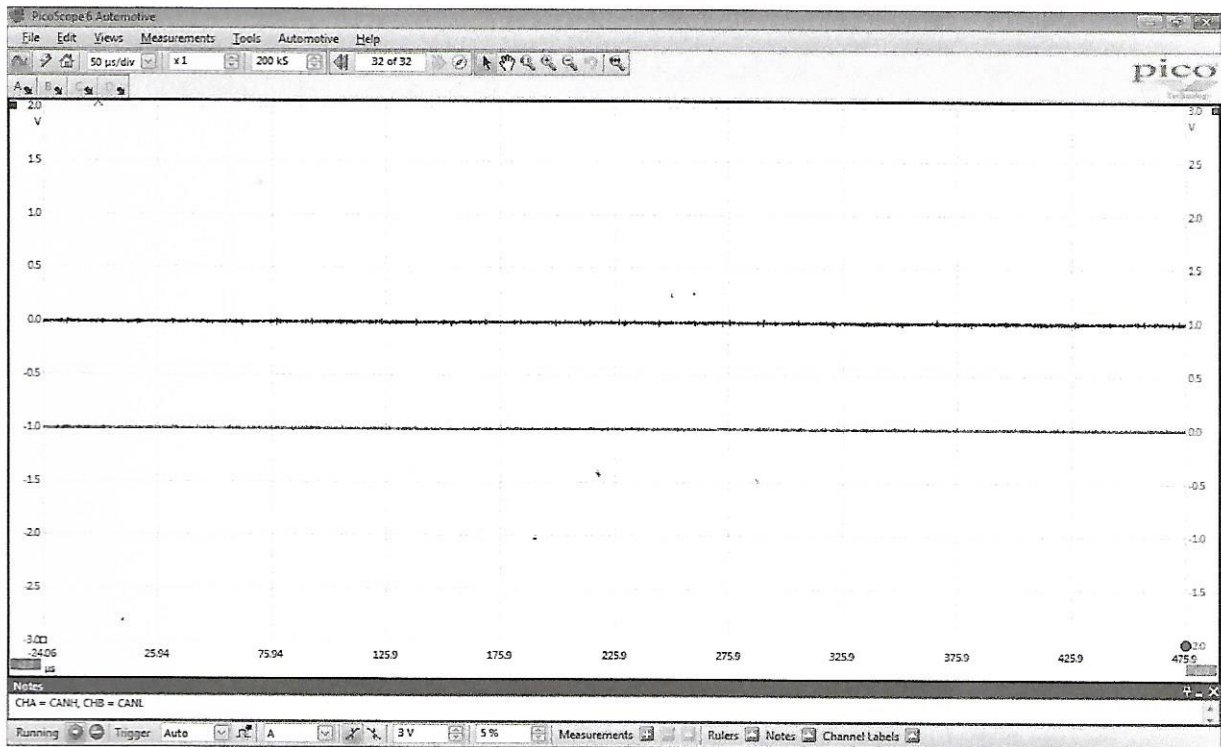


*CAN High is the upper waveform on the left side scale
CAN Low is the lower waveform on the right side scale*

CAN Bus uses a floating ground. This means that the ground circuit for the Transceivers is not connected to the chassis of the vehicle. The purpose of this design is that all Nodes do not require a common ground point and helps to isolate the circuit from interference. However, it also causes a fault on one side of the CAN Bus to cause a 'shift' on the other side of the circuit. This is evident on almost all CAN Bus faults. In this image you can see that the OPEN circuit on the CAN-High has caused the CAN-Low side OFF(IDLE) voltage to 'shift' from 2.5 Volts to 2.0 Volts. There is no fault on the low side.

WAVEFORM EXAMPLES continued...

CAN High and Low OPEN Circuit

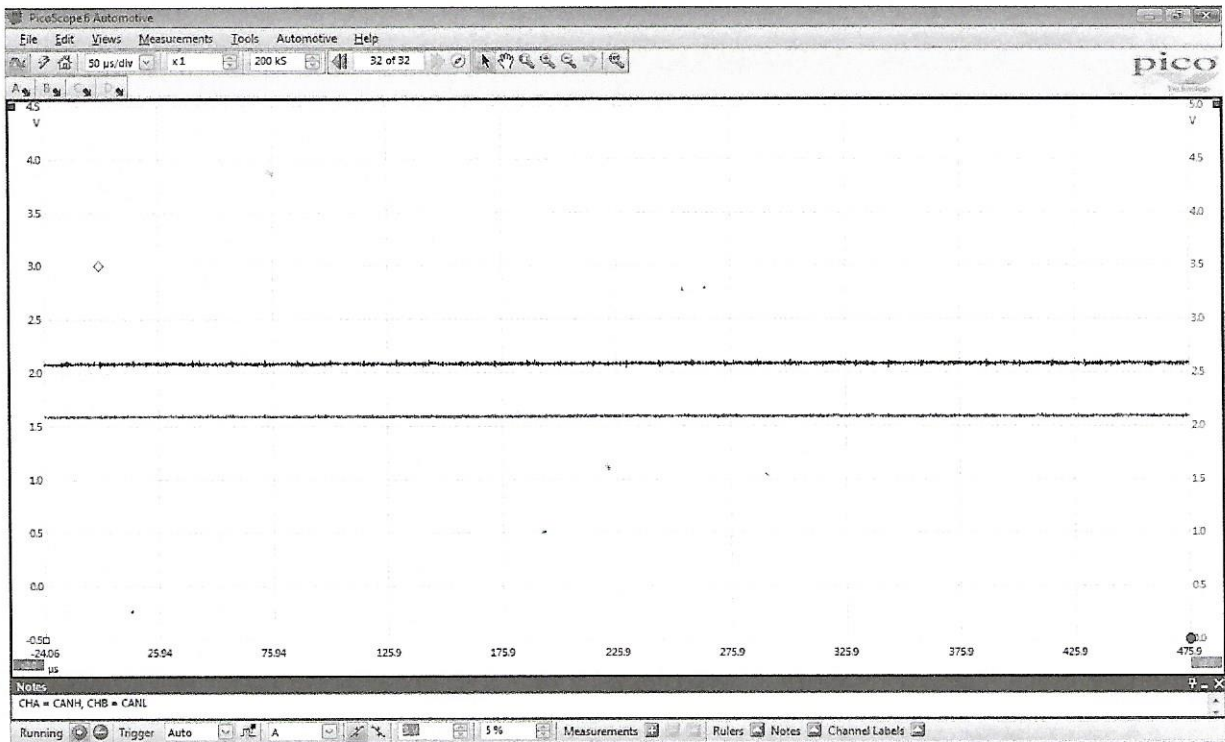


*CAN High is the upper waveform on the left side scale
CAN Low is the lower waveform on the right side scale*

This example shows that with both circuits open both Bus lines are at 0.0 Volts

WAVEFORM EXAMPLES continued...

CAN High and Low Short Circuit



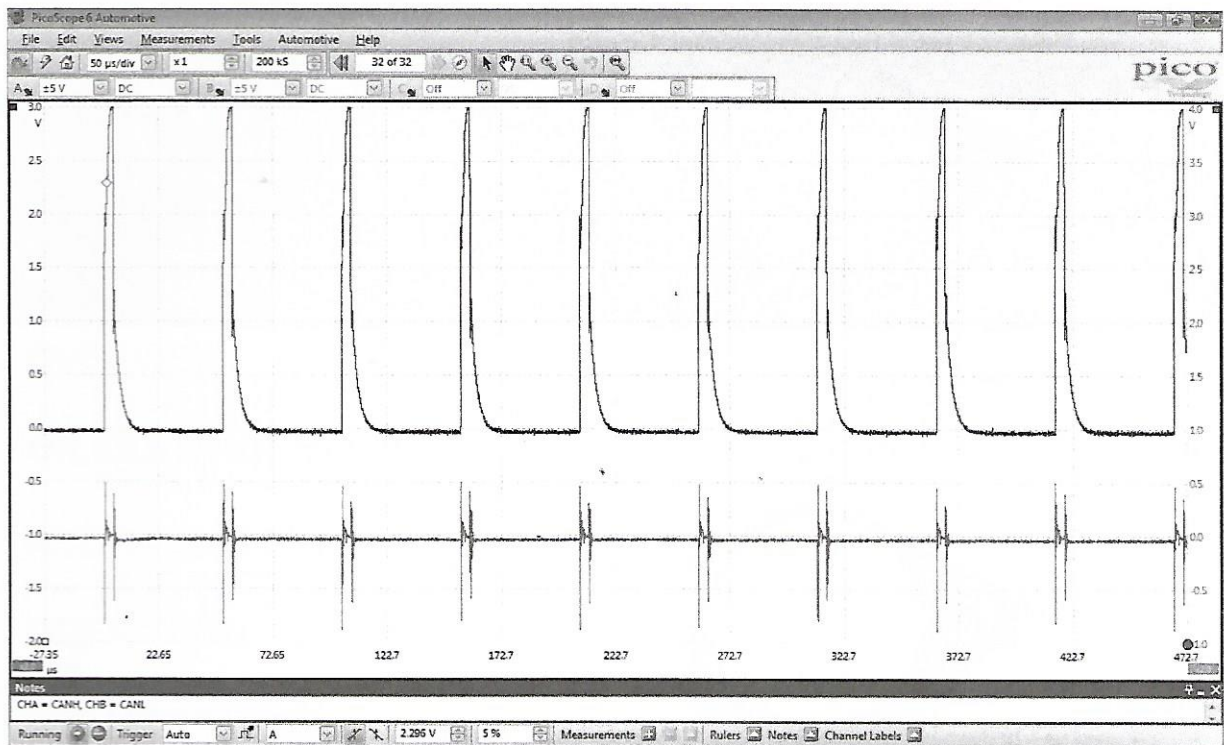
*CAN High is the upper waveform on the left side scale
CAN Low is the lower waveform on the right side scale*

This example also has two flat lines but the key difference is that shorting the CAN High and Low together has caused the voltages to be fixed.

- CAN High fixed at 2.1 Volts in this example
- CAN Low fixed at 2.1 Volts in this example

WAVEFORM EXAMPLES continued...

CAN Low SHORT to GROUND



*CAN High is the upper waveform on the left side scale
CAN Low is the lower waveform on the right side scale*

The CAN controllers have identified that a significant fault exists and are only sending 'pings' to check the network for a response. Some vehicles will send these test pings for a specific amount of time before putting the CAN Bus into Sleep Mode, others like this vehicle continue to send the test pings.

Again, the floating ground is evident on the shorted low bus line. If the circuit was chassis grounded the CAN-Low would be a fixed line on 0.0 Volts.

Module Before the module with all the DTC's is usually the faulty module. (Higher priority).

Disconnect that module & recheck scope pattern.

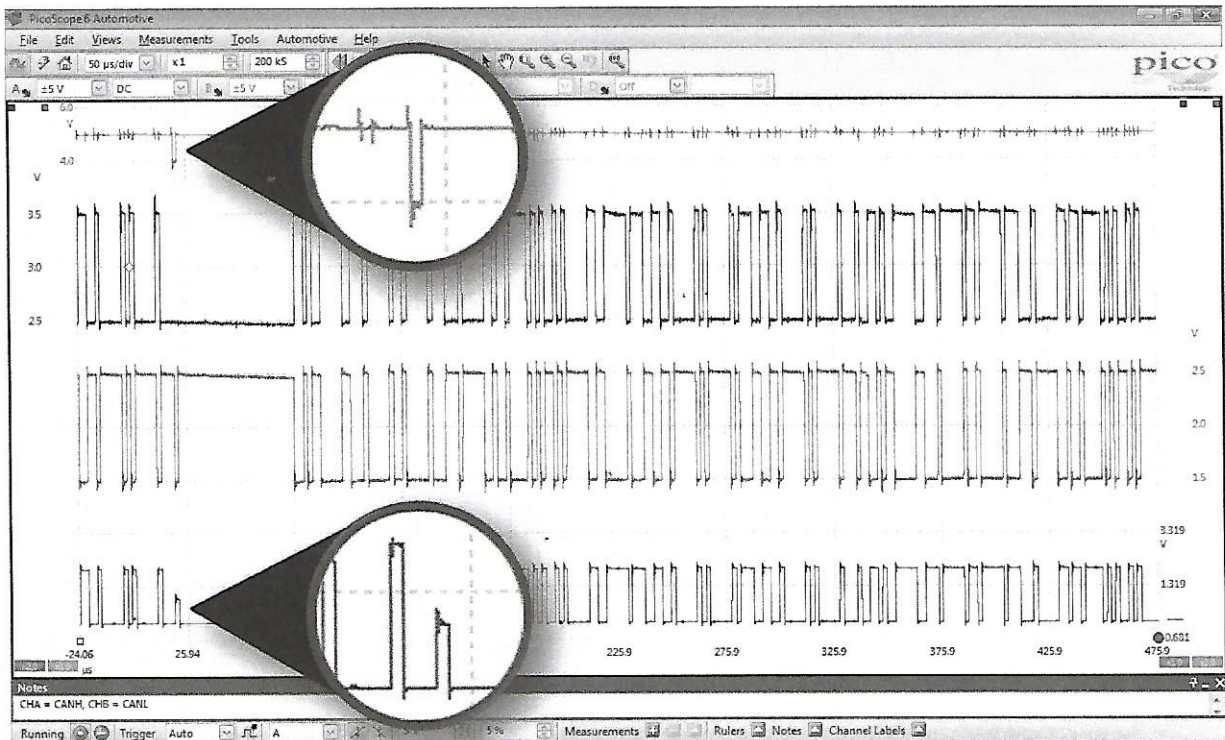
however the no. higher the priority.

If can high & low mirror each other can Bus is good.

(Best way to test comm. issues)

WAVEFORM EXAMPLES continued...

Corrupted CAN message



Math Channel A + B is the upper waveform on the adjacent left side scale

CAN High is the upper centre waveform on the adjacent left side scale

CAN Low is the lower centre waveform on the adjacent right side scale

Math Channel A - B is the lower waveform on the adjacent right side scale

The diagram above shows how using math channels on an oscilloscope makes picking CAN Bus errors and/or corruption easy. If you look closely, the last pulse of CAN-Low is missing on CAN-High.

The Math Channel A + B now shows a deviation from 5 Volts

The Math Channel A - B shows the last pulse at 1.0 Volts instead of 2.0 Volts

This example shows the communication error at the end of a sequence, if it was in the middle of a sequence it would be much harder to spot with the assistance of the Math Channel feature.